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Large-scale forcing impact on biomass variability in the South Atlantic Bight

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[1] The Gulf Stream western front (GSF) follows the shelf slope topography for a great extent of the South Atlantic Bight (SAB). Sub-surface intrusions of the Gulf Stream are known to provide nutrient-rich waters to the outer shelf regions of the SAB and, consequently, promote phytoplankton growth. These intrusions are much more frequent during summer and are responsible for a significant portion of the annual SAB shelf carbon production. Based on the analysis of satellite ocean color data, sea surface temperature (SST), sea surface height (SSH), and climatologic data sets, we present evidence for a connection between these Gulf Stream intrusions and the seasonal variability of the size and strength of the North Atlantic Subtropical Gyre (NASG). The intensity and frequency of intrusions depend on the proximity of the GSF to the shelf, which is modulated by the seasonal expansion and contraction of the NASG. **Citation:** Signorini, S. R., and C. R. McClain (2007), Large-scale forcing impact on biomass variability in the South Atlantic Bight, *Geophys. Res. Lett.*, *34*, L21605, doi:10.1029/2007GL031121.

1. Introduction

[2] The connection between the NASG variability and the SAB shelf response is the Gulf Stream forcing, which is the western branch of the NASG. Therefore, the size and strength of the NASG, which is governed by the large-scale wind circulation and seasonal solar radiation, has an impact on the oceanographic processes of the SAB [*Signorini and McClain*, 2006]. Plankton productivity is highly affected by upwelling and onshore movement of nutrients driven by lateral excursions of the Gulf Stream front [*Lee and Atkinson*, 1983; *Martins and Pelegri*, 2006; *McClain et al.*, 1990]. These upwelling events, also called Gulf Stream intrusions, occur mostly during the summer [*Atkinson*, 1985] when the Gulf Stream has a more onshore position [*Olson et al.*, 1983]. The frequency and extent of cross-shelf penetration of summer, subsurface intrusions is controlled by interactions between Gulf Stream and wind forcing, density of shelf waters (lighter and more stratified during summer), and bottom topography [*Atkinson*, 1977; *Atkinson et al.*, 1982; *Blanton et al.*, 1981; *Janowitz and Pietrafesa*, 1982]. During spring-summer, the Gulf Stream intrusions, or so called Gulf Stream-induced upwelling [*Yoder*, 1985], are felt shoreward of the 40 m isobath in conjunction with northward wind stress and cold upwelled waters intrude across the shelf beneath warmer shelf waters [*Atkinson*, 1977]. Thus, upwelling at the shelf break is forced by the Gulf Stream, but northward wind stress is required to move upwelled waters across the shelf [*Atkinson*, 1977; *Atkinson et al.*, 1984; *Blanton et al.*, 1981; *Hofmann et al.*, 1981]. The frequency and intensity of intrusions are therefore a function of the Gulf Stream western front proximity to the shelf break and the wind direction and strength. Gulf Stream intrusions are the major supplier of nutrients to the outer and middle SAB shelves, which are more frequent during the summer [*Atkinson*, 1985]. Our study shows a strong annual east-west translation in the position of the Gulf Stream front modulated by the seasonality of the size of the NASG, which expands during spring-summer, pushing the Gulf Stream closer to the shelf break. This seasonal translation of the Gulf Stream front has been previously documented by *Olson et al.* [1983], who found the Gulf Stream front all along the U.S. east coast to be further offshore in the late winter and early spring, in agreement with our findings. The impact of these summer intrusions on the SAB shelf phytoplankton production is quite significant due to the 'new' nitrogen being pumped onto the shelf. Individual summer intrusion events advect 0.3 to 1.8×10^4 metric tons of NO_3-N onto the northeastern Florida and Georgia shelves Atkinson et al., 1982].

[3] Gulf Stream upwelling is the major process affecting fates and dynamics of outer shelf and slope (40 to 200m isobaths) primary production [*Atkinson et al.*, 1978; *Dunstan and Atkinson*, 1976; *Verity et al.*, 1993, 2002; *Yoder*, 1985; *Yoder et al.*, 1983]. Plankton densities may change 10-fold or more within days [*Yoder et al.*, 1985]. Subsurface intrusions of North Atlantic Central Water (NACW) occur mostly from May to August [*Yoder et al.*, 1985]. With regard to Chl-a concentration on the shelf, most of phytoplankton production resulting from Gulf Stream intrusions during high stratification (summer) occurs near the bottom and is below the depth sensed by ocean color sensors. Therefore it is not possible to use satellite ocean color algorithms to accurately estimate mean vertical chlorophyll concentrations and primary production when these subsurface blooms are present [*Signorini and McClain*, 2005].

[4] This study focuses on the influence of remote forcing on the seasonal and interannual variability of Chl-a in the SAB based on satellite-derived products. The major source of data for this study is the 9-year ocean color time series originating from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). A major conclusion from this study is that biomass variability in the SAB outer shelf and slope region is primarily governed by the size and strength of the NASG via Gulf Stream excursions on the shelf break. Excursions of the Gulf Stream on and off the outer shelf and slope are largely driven by the seasonal variability of the NASG, which expands in the summer and contracts in the winter. The size and strength of the NASG can be determined from ocean color data because changes in Chl-a within the NASG respond to local physical processes. Ekman drift is one such process, but vertical mixing also plays a major role. Al-

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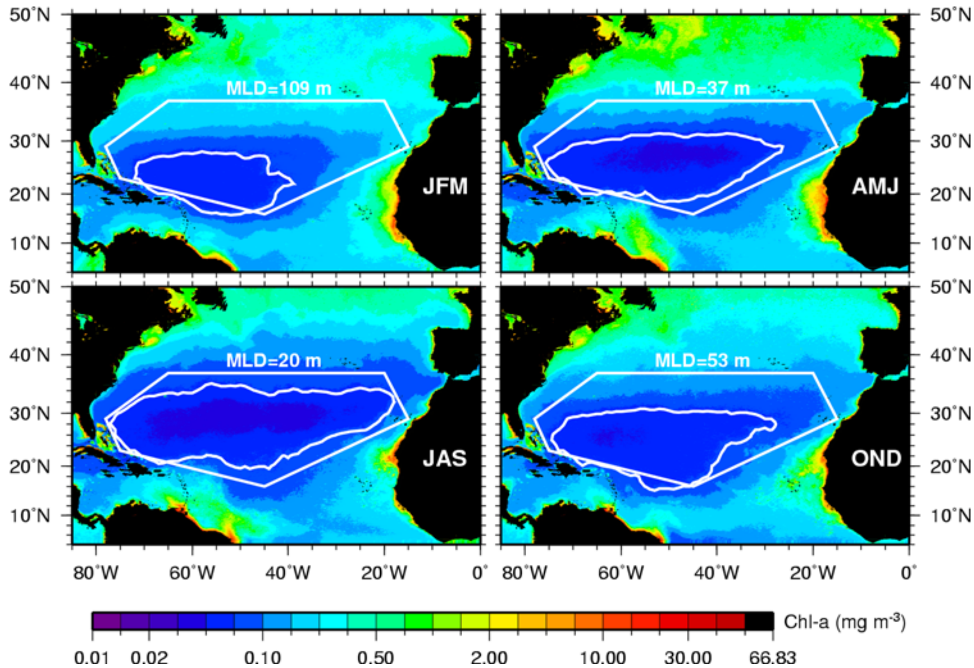

Figure 1. Seasonal composites of SeaWiFS-derived Chl-a. The white polygon delimits the control area of the NASG. The white contours are 0.07 mg m^{-3} Chl-a contours, and the mean MLD inside the polygon is shown for each season.

though it is not always straightforward to separate cause and effect when several processes act simultaneously on the Chl-a concentration, the role of subtropical gyres on Chl-a variability and the various processes involved have been previously studied [*McClain et al.*, 2004; *Williams and Follows*, 1998].

2. Data Sources and Methods

[5] Data analyzed included a time series of sea surface height anomaly (SSHA) from TOPEX/POSEIDON, sea surface temperature (SST) from the Advanced Very High Resolution Radiometer (AVHRR), and chlorophyll-a (Chl-a) derived from SeaWiFS 9-km Standard Mapped Images (SMI) and 1-km Local Area Coverage (LAC) products. Global dynamic height (DHT) 1/3° grids were produced by **S**egment **S**ol multimissions d'ALTimétrie, d'Orbitographie et de localisation precise (SSALTO) and Data Unification and Altimeter Combination System (DUACS) and distributed by the Archiving, Validation and Interpretation of Satellite Oceanographic data (AVISO) with support from the Centre National d'Etudes Spatiales (CNES). We also used monthly mixed layer climatologic data provided by the National Oceanic and Atmospheric Administration (NOAA), Boulder, Colorado, USA, from their web site at http://www.cdc.noaa.gov/, and sea surface height anomaly (SSHA) from NASA GSFC Ocean Altimetry Pathfinder Project. The size of the NASG was calculated from the ratio between the total number of Chl-a pixels with concentration less than 0.07 mg/m^3 to the total number of pixels inside a polygon delimiting the gyre domain (Figure 1). This ratio is an indicator for the expansion and contraction of the oligotrophic region of the gyre and thus its size and strength [*McClain et al.*, 2004]. The shape and size of the polygon was chosen in such a way to minimize coastal influence and contain the expansion of the chosen contour. The 0.07 mg/m^3 value was chosen to provide a closed contour throughout the seasons.

4. Summary and Conclusions

[13] A study of the effects of local and remote forcing of the Chl-a variability was conducted for the SAB based on the analysis of satellite-derived products. The seasonal position of the GSF was obtained using Aviso DHT and SeaWiFS Chl-a as indicators. South of 32°N, the western edge of the Gulf Stream generally lies within ±15 km of the shelf break. The front is closer to the shelf break in summer and moves offshore towards the winter. Immediately north of the Charleston Bump, a region where the Gulf Stream is deflected eastward and eddy generation is very active, the seasonal location of the front is much more variable. These excursions of the Gulf Stream front have an impact on the observed surface Chl-a and the concentrations change according to which side of the front the observation is taken and on the structures associated with the frontal eddies. East of the front the thermocline and nutricline are deeper, DHT is high and Chl-a is low. West of the front the relationship between DHT and Chl-a reverses.

[14] There is a connection between the NASG variability and the SAB shelf response via Gulf Stream forcing, which is the western branch of the NASG. The size and strength of the NASG, which is governed by the large-scale wind circulation and seasonal solar radiation, has an impact on the oceanographic processes of the SAB as a result of seasonal Gulf Stream onshore/offshore motion. Our study shows that the GSF seasonal position can be detected by ocean color satellites and that it moves closer to the shelf break during summer when Gulf Stream subsurface intrusions are more frequent and intense, as demonstrated by numerous *in situ* studies. The intensity and frequency of intrusions depend on the proximity of the GSF to the shelf, which is modulated by the seasonal expansion and contraction of the NASG.